ET-2000
EXTRUDER GUARDRAIL
END-TERMINAL

Construction Report

Experimental Features
Project No. 93-06

Coos Bay - Roseburg Highway
O'Xing S.P.R.R. - I-5
Douglas County

By

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16. Abstract

An ET-2000 Extruder Guardrail End Terminal (GET) was installed in September 1993 along a state highway in southern Oregon. The ET-2000 GET was installed to reduce the severity of injuries during accidents and to reduce the amount of land (right-of-way) required for the guardrail. The ET-2000 GET was installed as planned - there were no major problems during construction.

The performance of the ET-2000 GET should be evaluated by ODOT staff for at least two years. Based on the successful experiences of other states, ET-2000 GET should be allowed to be used as an alternative guardrail end terminal. Any additional ET-2000 GET's installed by ODOT should be monitored.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

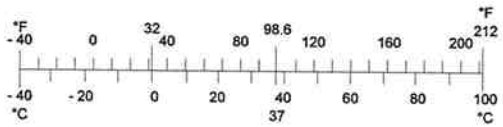
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

(4-7-94 jbp)

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DISCLAIMER

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1.0 INTRODUCTION

The ET-2000 GET was researched and developed by the Texas Transportation Institute (TTI) at Texas A&M University, in cooperation with The Texas Department of Transportation (TxDOT) in their earlier effort to develop the Guardrail Extruder Terminal (GET). The GET was developed to eliminate the spearing and vaulting effects motorists were experiencing with older guardrail terminal designs.

> *ET-2000 was designed to be the end treatment to make guardrail collisions survivable. And it has. Prior to the development of ET-2000, most transportation agencies in the U.S. installed either the Turndown end treatment or the Breakaway Cable Terminal (BCT), neither of which meets National Cooperative Highway Research Program (NCHRP) 230 safety requirements. While these earlier end treatments were a vast improvement over unprotected guardrail ends, collision with them often results in serious injury (1).*

Although approved for use on September 6, 1989, the Federal Highway Administration (FHWA) classified the ET-2000 GET as operational in the fall of 1991, and since then, its use is becoming widespread throughout many DOT's (2). Further, the terminal does meet or exceed the requirements of NCHRP Report 230, entitled Performance Evaluation of Highway Appurtenances.

In Oregon, an ET-2000 Extruder Guardrail End Terminal (ET-2000 GET) system was installed in September 1993. This guardrail end terminal system is the first of its kind in Oregon, and is being utilized for its ability to improve safety and reduce the amount of land (right-of-way) required for the guardrail.

2.0 PROJECT DESCRIPTION

2.1 PROJECT LOCATION AND CLIMATE

The project is located near mile post 76 on the north side of the Coos Bay-Roseburg Highway (U.S. Route 99), four miles southeast of Roseburg, Oregon as shown in Figure 2.1.

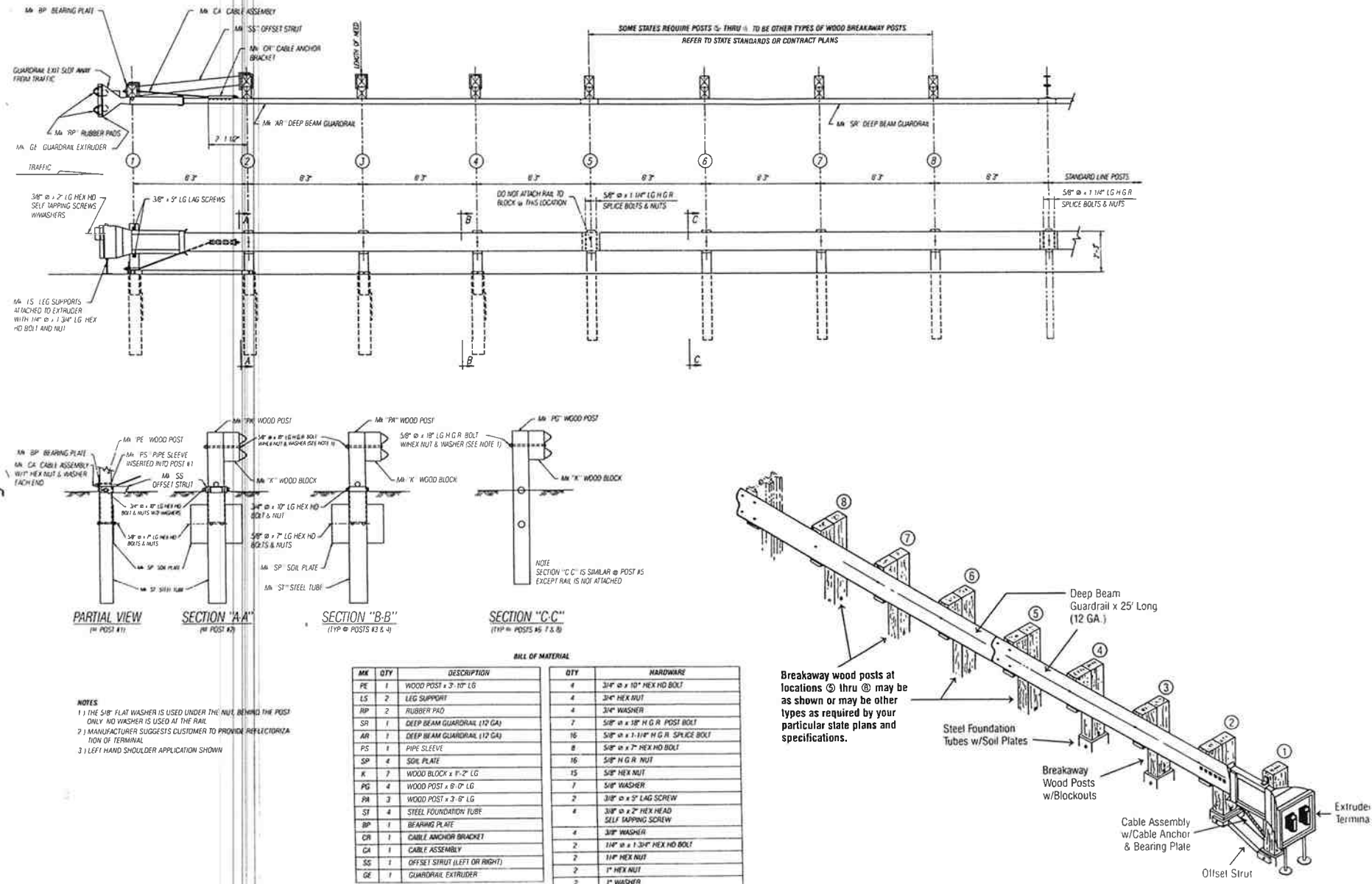
The project is in the Umpqua Valley climatic region, which is characterized by mild wet winters and moderate dry summers. The average daily maximum temperature during the coldest month (January) is about 43.2°F (6.2°C); the average daily minimum temperature is approximately 19.7°F (-6.8°C). The average daily maximum temperature of the warmest month (August) is approximately 90.9°F (32.7°C); the average daily minimum temperature is about 52.5°F (11.4°C). This area receives an average annual precipitation of 33 inches (84 cm).

2.2 DESIGN

The ET-2000 GET is typically comprised of eight standard guardrail posts which continue in-line with the guardrail section they are attached to. The posts are made to fit into eight steel foundation tubes with soil plates. In Figure 2.2, various components of the ET-2000 GET are shown, including seven "crushable" spacer blockout blocks, two standard 2'-0" long deep beam guardrails, one cable assembly with cable anchor and bearing plate, one offset strut, and the guardrail extruder terminal head.

Because of its innovative design and rather simple installation, the ET-2000 GET system may be an effective device that reduces spearing, vaulting, and rollovers commonly experienced in other highway accidents. Also, when the ET-2000 GET is struck, it may effectively redirect the vehicle. The ET-2000 GET works as follows:

> *When struck, the impacting vehicle forces the extruder terminal along the guardrail, shearing the wooden posts and curving the end of the guardrail away from traffic right-of-way as it brings the vehicle to a controlled stop. Kinetic energy generated by the impact is absorbed by the force required to flatten the guardrail in the extruding process (3).*



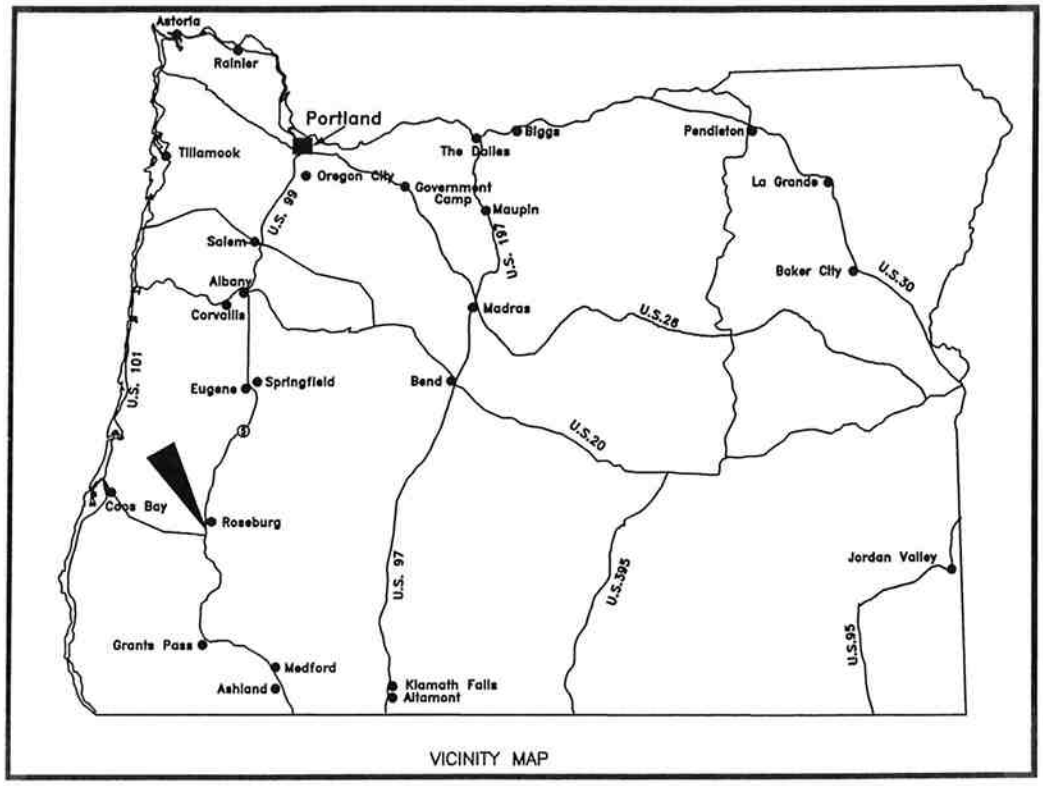
BILL OF MATERIAL

MK	QTY	DESCRIPTION
PE	1	WOOD POST x 3'-10" LG
LS	2	LEG SUPPORT
RP	2	RUBBER PAD
SR	1	DEEP BEAM GUARDRAIL (12' GA)
AR	1	DEEP BEAM GUARDRAIL (12' GA)
PS	1	PIPE SLEEVE
SP	4	SOIL PLATE
K	7	WOOD BLOCK x 1'-2" LG
PG	4	WOOD POST x 6'-0" LG
PA	3	WOOD POST x 3'-6" LG
ST	4	STEEL FOUNDATION TUBE
BP	1	BEARING PLATE
CR	1	CABLE ANCHOR BRACKET
CA	1	CABLE ASSEMBLY
SS	1	OFFSET STRUT (LEFT OR RIGHT)
GE	1	GUARDRAIL EXTRUDER

QTY	HARDWARE
4	3/4" ø x 10" HEX HD BOLT
4	3/4" HEX NUT
4	3/4" WASHER
7	5/8" ø x 18" H.G.R. POST BOLT
16	5/8" ø x 1-1/4" H.G.R. SPLICE BOLT
8	5/8" ø x 7" HEX HD BOLT
16	5/8" H.G.R. NUT
15	5/8" HEX NUT
1	5/8" WASHER
2	3/8" ø x 5" LAG SCREW
4	3/8" ø x 2" HEX HEAD SELF TAPPING SCREW
4	3/8" WASHER
2	1/4" ø x 1-3/4" HEX HD BOLT
2	1/4" HEX NUT
2	1" HEX NUT
2	1" WASHER

NOTES
1.) THE 5/8" FLAT WASHER IS USED UNDER THE NUT, BEHIND THE POST ONLY. NO WASHER IS USED AT THE RAIL.
2.) MANUFACTURER SUGGESTS CUSTOMER TO PROVIDE REFLECTORIZATION OF TERMINAL.
3.) LEFT HAND SHOULDER APPLICATION SHOWN

Figure 2.2: ET-2000 Extruder Guardrail End Terminal Design



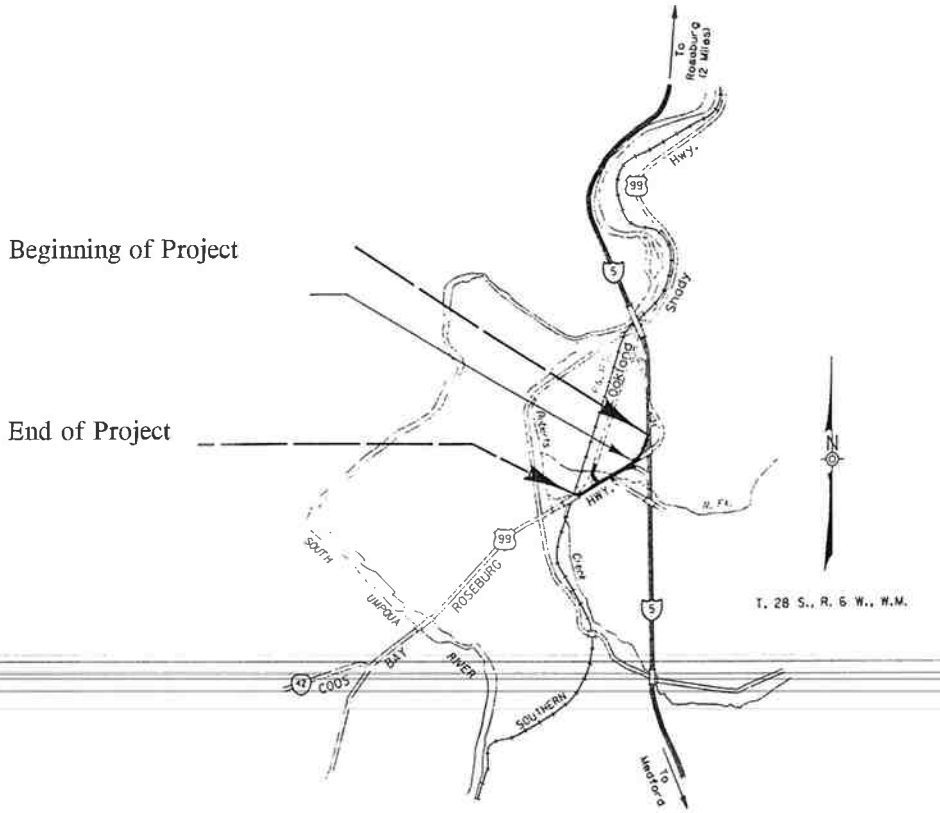


Figure 2.1: Project Location in Oregon

3.0 CONSTRUCTION

The ET-2000 GET was installed along the Coos Bay - Roseburg Highway in accordance with the special provisions and specifications (*4*) for the "O'xing S.P.R.R. - I-5 Section" project. Syro Steel delivered the entire ET-2000 GET system as a complete package to the installation site. Construction of the ET-2000 GET began at approximately 10:35 a.m. and was completed at approximately 11:45 a.m. on September 8, 1993. The work was performed by Coral Construction Company (Wilsonville, OR), who is a sub-contractor to Bracelin-Yeager, Inc., the prime contractor (Coos Bay, OR). Coral Construction utilized one drill and auguring rig/truck, one operator, and two laborers to perform the installation. In essence, the installation went as planned, much the same as any typical guardrail system.

Some state agencies have experienced difficulties in installing the Mk-ST steel foundation tubes, however. The foundation tubes are bolted to the Mk-SP soil plates and under certain soil conditions, driving this assembly could create deformations which make it challenging to insert and/or remove the wood posts. In addition, occasionally, "one or both of the bolts that are intended to hold the soil plate to the tube sometimes break, as may be evidenced by the plate's presence at ground level (*5*)."

> *When inserted into the tube, the wood posts stand atop these two bolts. The soil level inside the tube after driving is often above the level of the soil plate's bolts. This soil should be scooped out before the post is placed in the tube, for it may otherwise contribute to the bolts' breakage and to the greenwood fractures that sometimes occur alongside of the drilled breakaway hole when the wood post must be driven into place (5).*

Further, changes and considerations to improve the installation and operation of the ET-2000 GET design are being submitted by agencies that use the terminal unit. Again, the installation of ET-2000 GET in Oregon went quite smoothly.

4.0 COSTS

4.0 COSTS

The cost of the ET-2000 GET attenuator head is approximately $750.00. The complete, fully-featured, unit costs $2,125.00; the bid item cost on the project was $3,000.00. Approximately $100 - $130 of additional costs are added for purchasing less than five units at once (*6*).

The ODOT Project Manager's office summary of the ET-2000 GET terminal installation are as follows:

Laborer (1)	*1.5 hrs @ $25/hour*	= $ 37.50
Operator (1)	*1.5 hrs @ $28/hour*	= $ 42.00
Post Driver (1)	*1.5 hrs @ $50/hour*	= $ 75.00
1-Ton Flat Bed (1)	*1.5 hrs @ $16/hour*	= $ 24.00
10-T Trailer (1)	*1.5 hrs @ $3/hour*	= $ 4.50
ET-2000 GET (1)	*(Complete Unit)*	= $2,125.00
TOTAL INSTALLATION COST:		= $2,308.00
BID ITEM #58 UNIT PRICE:		= $3,000.00

The cost of the ET-2000 GET is significantly less than other guardrail end terminal systems when considering that the rest of the unit is practically the same as a typical guardrail section except for the use of steel sleeves which more easily allow the timber posts to be removed and repaired during maintenance. Thus, the maintenance cost of repairing the entire unit are virtually the same as repairing a typical guardrail section. This is because the ET-2000 GET attenuator "head" is usually not damaged when hit and can be reused many times over, allowing for the rest of the unit to be repaired in a typical manner.

When further considering the costs, Mr. Mark Marek, Engineer of Geometric Design at TxDOT, was disappointed with the pricing of the ET-2000 GET. When TxDOT initially purchased and became the first users of ET-2000 GET, they were notified by Syro, Inc. that the pricing would decrease over time as TxDOT continued to purchase the unit in greater volumes. However, since then, Syro, Inc. has become a subsidiary of a company called Trinity Industries of Girard, Ohio. Trinity Industries has decided to increase the price of the ET-2000 GET system to more closely match competitor pricing of more expensive systems. While the price of the ET-2000 GET still remains below that of other competitor products, it has not decreased, like Mr. Marek thought it would. He said that he would have selected a less expensive FHWA approved end treatment if one was available. In essence, if TxDOT had been able to anticipate

the ET-2000 price increases of Syro, Inc., as a result of its new "parent" company's policies, perhaps they would have chosen an alternative end treatment; that is, an end treatment comparable to the ET-2000 GET's performance.

As Mr. Doug Gendron, of the Indiana Department of Transportation, (INDOT) explains:

> *This product was developed in Texas, and prototype units were allegedly individually manufactured for about $600 - $700 less than the cost of materials from the present manufacturer. TxDOT officials had expected to pay less than $2,000, installed, and expressed dismay at the average installed cost - about $2,600 - of the ET-2000 GET (5).*

In the mean time, TxDOT has tried using a proto-type design made by prison inmates through their prison system. The unit was nearly identical to the ET-2000 GET, but was blocked from further production by an FHWA regulation. I then asked Mr. Marek what alternative end treatments are available. He mentioned that there are basically only four types of end treatments available: one, the "Turn-down"; two, the "Break-Away Cable Terminal (BCT)" and its many derivatives; three, the "Sentre" guardrail shoulder end terminal by Energy Absorption Inc.; and four, the "ET-2000 GET" by Trinity Industries (7). These and three other similar systems, commonly used on highway systems throughout the United States, are included in Table 4.1.

Table 4.1: Common Shoulder Guardrail End Terminal System Comparison

System Name	Manufacturer	Cost/Comment
Brakemaster	Energy Absorption Systems, Inc.	~ $4800 - $5000
Breakaway Cable Terminal	Non-Proprietary	~ $550 - $1000
Crash Cushion Attenuating Terminal (C.A.T.)	Syro, Inc.; a subsidiary of Trinity Industries, Inc.	~ $3500 - $5000 installed
ET-2000 Guardrail Extruder Terminal	Syro, Inc.; a subsidiary of Trinity Industries, Inc.	~ $1700 - $3500 installed Average = $2583 installed
Safety Barrier End Treatment (Sentre)	Energy Absorption Systems, Inc.	~ $300 - $400 installed
Transition End Terminal (Trend)	Energy Absorption Systems, Inc.	~ $4500 - $5500 installed
Turndown	Non-Proprietary	~ $550

Of interest, when pricing the ET-2000 GET, is a recent effort to establish a national price agreement between Trinity Industries, Inc. and agencies and corporations purchasing the ET-2000 GET. Since speaking with Mr. Marek about the price fluctuations TxDOT was experiencing, Trinity Industries has finalized a national pricing policy; this as a result of TTI's earlier request for developing such an agreement (*8*). Below, is an example of this new policy:

Table 4.2: ET-2000 Guardrail Extruder Terminal Manufacturer Pricing (Trinity Industries National Pricing Agreement Prices Prior to Installation)

Option	Price	Option Includes:
A	$2125.00	50 ft. (15.24 m) length, 8 posts, 7 blockout blocks, 8 foundation tubes
B	$1805.00	50 ft. (15.24 m) length, 8 posts, 7 blockout blocks, 4 foundation tubes
C	$1750.00	25 ft. (7.62 m) length, 8 posts, 7 blockout blocks, 4 foundation tubes

Individual states purchasing prices varied with Trinity Industries depending on the number of units bought at one time. As indicated previously, there are additional charges for buying less than five units on an order. Recently, Ohio was able to purchase 50 units at $1,500 each which is below Trinity's pricing policy. Other states like Illinois and Montana paid $2,600 for their units in April 1993. The average manufacturer unit price from Trinity is $1,800 (*9*).

5.0 ADDITIONAL INFORMATION

Additional information related to the ET-2000 GET will be discussed in this chapter including the benefits, experiences of other states, accident history, safety/reflectivity, parts inventory, technical advice, and training.

5.1 BENEFITS

The ET-2000 GET is installed similar to typical guardrail applications. The unit does not "flare" from the in-line direction of the guardrail section it is attached to. However, it should be noted that some state transportation agencies are including a "flare", and/or "earthen pads" where appropriate applications of those design criteria are necessary. The implications of using a "flare" are discussed, in the next section. "Earthen pads" are something used and mentioned by Mr. Doug Gendron of the INDOT. The pads help provide a flat area for the unit to rest upon. The FHWA approval letter to Syro Steel (September 6, 1989) emphasizes the "desirability" of a flat area behind the terminal so that the severity of accidents can be minimized, and vehicle stability enhanced in order to decrease the chances of spin out and/or rollover (*10*). Mr. Gendron further pointed out that a flat area and proper landscaping will reduce soil erosion around each of the guardrail posts steel soil tubes, and thus, inhibit their likelihood of protruding above the ground, and catching a vehicle's underside (*11*). On the whole, ET-2000 is right-of-way frugal and space saving. It requires no special surveying and construction work (other than that of laying out a typical guardrail section), since concrete pads, foundation work, and such, which are needed for other end terminal attenuators, are not required here. In addition, the overall cost of installing the ET-2000 is significantly less than other systems; especially when considering the associated material and labor costs external to the actual attenuator unit. An example of this is the construction expense required for the foundation and approach pad work with the Transition End Terminal (Trend).

5.2 EXPERIENCES OF OTHER STATES

The ET-2000 GET is being used throughout the United States. Users in the United States include those listed in Table 5.1.

Table 5.1: ET-2000 Extruder Guardrail End Terminal Usage Log

AGENCY/CONTACT	UNITS INSTALLED	NUMBER OF "HITS"	START UP	COMMENT
Alabama DOT Lab Larry Locket 205-242-6539	0	0	-	
Arizona DOT Hwy.Plans Terry Otterness 602-831-2620	54	1	1993	Approved product status 09/15/93. ~ $3000.00 installed.
Caltrans Traffic Oper. Jack Summers 916-654-7055	3	0	1992	Easy installation and cheaper than other alternatives.
Colorado DOT Research Skip Outcalt 303-757-9506	2	0	1992	Satisfied with installation.
Idaho DOT Bob Smith 208-334-8437	0	0	-	"Experimental Features" status, but none ordered yet.
Indiana DOT Research Doug Gendron 317-463-1521	13	0	1993-1994	Handles accidents better on shoulders than other systems. Landscaping design change utilized around unit's foundation. $2750 installed bid on 13 units. "Upstream" flare incorporated.
Maryland DOT Research Peter Phillips 410-333-1808	42	0	1993	40 more units under contract; ~$1200 installed price for the 42 unit 8/93 installation; reflective nose cover used.
Michigan DOT Vic Childers 517-335-2991	50	1	1992	Simple system; Excellent! Wants certified installers. ~$1700 - $3500 installed.
Minnesota DOT Glen Korfhage 612-296-4859	100+	10-15	1990	Excellent! ~$2900 installed. Design change to include an "upstream" flare; avoid snowplow equipment.
Montana DOT Bob Tholt 406-444-6008	7	0	1992	~ $3100 installed.
Nevada DOT Gary Wood 702-687-3452	16	0	1994-1995	Product evaluation status for field testing. Contract pending; bid item cost @ $1200/unit prior to installation.

AGENCY/CONTACT	UNITS INSTALLED	NUMBER OF "HITS"	START UP	COMMENT
New Mexico Hwy Dept. Phillip Ramos 505-827-5528	5 units scheduled for 12/93	0	1993	Approved product status, 10/28/93. ~ $3500/unit, bid item cost.
Ohio DOT Brett Gilbert 614-752-4352	1000+	75+	1991	Excellent performance! A bit expensive, but best alternative. Approved status 1992. No fatalities. Expects 3000 - 4000 total units in place end of 1994.
Oregon DOT Mike Dunning 503-986-3059	1	0	1993	~ $2308 installed price by Coral Construction, Inc. Bid item cost was $3000.
Pennsylvania DOT Paul Kokos 717-783-5110	75-100	0	1992	~ $3000 installed.
Sierra Pacific Power John Owens 702-689-3745	4	0	1992	ET-2000 GET used to protect two substations from both directions of travel. ET-2000 was less expensive than other alternatives reviewed.
Texas DOT Mark Marek 512-416-2653	1000+	30-40	1989	Very satisfied with performance. Disappointed with cost increases. Most accidents were "drive-aways". One fatality, unrelated to unit's performance. One extruder head damaged, repaired, and returned to service after being hit by semi-tractor/trailer. "Upstream" flare incorporated.
Utah DOT Mac Christensen 801-965-4264	6	0	1992	ET-2000 GET: Favorable price. Settled on M.E.L.T., however, because of non-proprietary product nature; not sole source dependant.
Washington DOT Don Gripne 206-705-7263	0	0	-	Unit is approved for use.

Although early performance evaluations of the ET-2000 GET seem to indicate that the end terminal unit is performing in a satisfactory manner, there is the need to address some of the concerns relating to its operation and function when the unit is hit. The Ohio Department of Transportation has conducted an evaluation to judge the effectiveness of the ET-2000 GET (*12*).

This report, *Guardrail End Treatment Evaluation Report*, indicates that revisions were made to their Department's Revised Guardrail End Treatment Policy, and that new guidelines for reporting guardrail end terminal accidents and evaluation procedures are being established. Some of this work has led to an accident matrix entitled "Summary of Accidents Involving the ET-2000 GET." "It is evident from the matrix that most accidents happened in the freeway environment. The "average" accident seems to be an impact at zero degrees and at 5-10 mph under the legal speed. Occupant injuries are mostly none or minor (*12*)." Accident reports are indicating that the ET-2000 is working relatively well, and that the terminal is safely performing as designed by bringing motorists to a controlled stop in an end-on accident (*12*). However, these same reports also showed the Ohio DOT that there are some areas of concern. Four concerns are outlined in their report and each of these were further reviewed recently with Mr. Ken Linger, a roadway maintenance engineer for the Ohio DOT Bureau of Maintenance, who has been working directly with the ET-2000 GET (*13*). Apparently there is the tendency of the following to occur:

1. Upon impact, the sheared wood posts may be propelled downstream. Posts have been found 100+ feet downstream and approximately 40 feet to the right of the pavement. This could have serious implications for on-coming traffic in opposing travel lanes.

2. Upon impact and extrusion, the guardrail may buckle. In other cases, the ET-2000 may be hooked and pulled onto the travelled lane or shoulder.

3. Vehicle redirection back into the adjacent traffic may occur, such as the possibility where a vehicle is spun into the traveled lane or shoulder. In an opposite fashion, during "downstream" hits with the guardrail, the unit has even been known to "gate" or act as a moveable barrier and essentially allow the vehicle to pull the unit and its associated rail onto the fore-slope and off of the roadway; no injuries were reported in those situations.

4. Damaged end terminal units after being impacted can become a traffic hazard until repairs are made.

Two of these concerns were brought to the attention of Mr. Dean L. Sicking, a professor at the University of Nebraska. Professor Sicking played a important role in the development of the GET when he earlier worked for TTI. Mr. Sicking indicated that flying posts are not limited to the GET and are no more of a problem with the ET-2000 than in other terminal systems. Mr. Sicking further indicated: "buckling is part of the design of the terminal. It will only extrude at an impact angle of -1 to 1 degree (*12*)." The unit is designed so that hitting it at the terminal's end allows the vehicle to pass through, while hits further downstream should redirect the vehicle. Hooking, as mentioned above, can more easily be avoided by utilizing an "Offset Design" option which uses an extruder head offset of nine inches (0.2286 m) so that vehicle clipping, of the unit, can better be prevented. The issues of vehicles being spun and those that "gate" when contacting the unit are ones for further review and tracking. Finally, the hazard

presented by damaged units on the roadsides can be reduced through providing temporary safety markings and reflective devices such as cones or drums (*12*).

During a recent conversation with Mr. Linger, he mentioned that Trinity Industries was allowing the unit to flare 2% over its 50 foot (15.25 m) length from post eight to the extruder head. This works out to a one foot (0.3048 m) offset of the extruder, and helps eliminate some of the "nuisance hits" Ohio and others were experiencing (*13*).

5.3 ACCIDENT HISTORY

In Texas, approximately 1000 units have been installed since 1989. Between 30 to 40 "hits" have occurred there, of which most of these were "drive-aways" where no accident reports were filed and where individuals simply drove away from the scene. When the ET-2000 GET is "hit," it is usually by cars and pickup trucks; the highest reported vehicle/terminal collision speed was approximately 80 mph. TxDOT's Mark Marek says that the ET-2000 GET works, and that TxDOT is satisfied with its performance. The actual ET-2000 GET extruder terminal head was damaged only once and that was by an "18-wheeler" semi-tractor/trailer truck. This "head," was later repaired and put back into service (*7*). It is very hard to destroy the extruder terminal head.

5.4 SAFETY/REFLECTIVITY

Actual documented experience is proving the ET-2000 GET to be a safe guardrail end treatment alternative when being "hit," resulting in no fatalities, and minor (if any) injuries. Some of the current experience of other agencies was discussed previously.

When considering reflectivity, the FHWA recommends that the front surface of the unit be reflectorized. An optional reflective "nose-cover" is available for $75.00 from Syro, Inc., and it can be easily applied to the terminal head.

5.5 PARTS INVENTORY

The ODOT maintenance shops have approximately two-thirds of the required parts to maintain the ET-2000 GET system. Again, aside from the actual terminal head, the system's unit is similar to that of a typical guardrail section. When speaking with Mr. Marek of TxDOT, I mentioned that ODOT may already have 2/3 of the parts, required to repair the ET-2000 GET, in stock. He thought that this may very well be the case because ODOT uses the Breakaway Cable Terminal, BCT, quite a lot and its parts are supposedly similar; this was not the situation in Texas, however, and initially stocking repair parts for the ET-2000 GET, at all of their maintenance yards, was expensive (*7*). Mr. Roger Alfrey of Syro, Inc., Centerville, Utah, indicated that he made a small survey of some of our maintenance yards during his visit to assist

with ODOT's ET-2000 GET installation. The BCT and its replacement parts, in fact, are used and stocked quite extensively here in Oregon. Mr. Alfrey said that stocking the ET-2000 GET parts with the BCT parts is easy to do since the only parts we do not already have in-stock are just those of the extruder head and perhaps the 25 foot sections of guardrail; typically, other sections we stock are longer (*9*).

5.6 TECHNICAL ADVICE

Technical advice during installation, repairs, and maintenance is usually available from Syro, Inc.; the Syro representative was present for ODOT's ET-2000 GET installation, and was quite familiar with Coral Construction, the sub-contractor who installed the unit. Further, he was able to assist the contractor, during installation, and said that he would also be available to help with assisting in the repair of our unit if it is hit.

5.7 TRAINING

Training required to install and maintain the ET-2000 GET system is simple and similar to a typical guardrail section which ODOT staff are already familiar with. Some state agencies expressed an interest toward having contractors, inspectors, and maintenance personnel specially certified to install, inspect, and maintain the ET-2000 GET. However, Mr. Gendron's construction report for the INDOT stresses the importance of why clear guidance and unified standards of installation are critical to the ET-2000's performance success; for example:

> *It can be critical to the correct performance of the ET-2000 GET that the Mk-AR Deep Beam Guardrail's upstream end terminate within, not merely near to, the Mk-GE Guardrail Extruder's interior chamber. There is good reason to not tolerate a visible gap between the rail end and the Extruder's chamber edge. Otherwise, in some impact scenarios the chamber edge and rail end could jam. In such cases the Extruder may not work as the manufacturer intends: the rail could be forced to buckle, or vehicle penetration could occur by the guardrail end or by a newly formed point. Syro intends for the rail end to be fully enclosed, but did not say so in their manual. Without clear guidance on this point, contractors and inspectors may accept unacceptable units. It would be helpful to have a specified minimum length for the rail end to be installed within the Extruder chamber, in consideration of normal rail expansion and contraction* (*5*).

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The installation of the ET-2000 GET was performed according to the plans and specifications in a very timely manner. The required tools and equipment, and the necessary human resources and knowledge to install this device is much the same as that needed for any typical guardrail section used and installed previously in Oregon. Presently, ODOT uses the Breakaway Cable Terminal (BCT) quite extensively. Because of this fact, stocking parts for and maintaining the ET-2000 GET may be easier since the two systems are similar in some ways.

Experiences of other states is indicating that the ET-2000 GET is meeting or exceeding many performance expectations, and doing so at a reasonable cost. The unit is commonly installed for between $1,700 and $3,500 with an average installed cost of approximately $2,583; the bid item cost was $3,000 for this particular project in Oregon. The ET-2000 GET is, on average, $2,077 below the cost of other proprietary products like the Brakemaster, the C.A.T., the Sentre, and the Trend. A national pricing policy has been established between Trinity Industries, Inc. and the agencies and corporations purchasing the ET-2000 GET. A pricing structure of this sort will help stabilize the price fluctuations being seen in the market and provide for more uniformity in general (*14*).

Because of its innovative design and rather simple installation, the ET-2000 GET is performing as an effective device toward eliminating spearing, vaulting, and rollovers commonly experienced in other highway accidents. On the whole, the ET-2000 GET is right-of-way frugal and space saving. It requires no special surveying and construction work (other than that of laying out a typical guardrail section), since concrete pads, foundation work, and such, which are needed for other end terminal attenuators, are not required here. In addition, the overall cost of installing the ET-2000 GET is significantly less than other systems; especially when considering the associated material and labor costs external to the actual attenuator unit. Finally, the low number and severity of accidents reported from other states indicate that the ET-2000 GET is working relatively well, and that the terminal is safely performing as designed by bringing motorists to a controlled stop (*12*). These same reports, however, also showed the Ohio DOT that there are some areas of concern which should continue to be monitored and tracked through new and effective reporting methods.

6.2 RECOMMENDATIONS

The performance of the ET-2000 GET should be evaluated by ODOT staff for at least two years. Based on the successful experiences of other states, ET-2000 GET should be allowed to be used as an alternative guardrail end terminal. Any additional ET-2000 GET installed by ODOT in the near future should be monitored.

7.0 REFERENCES

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APPENDIX

PHOTOGRAPHS

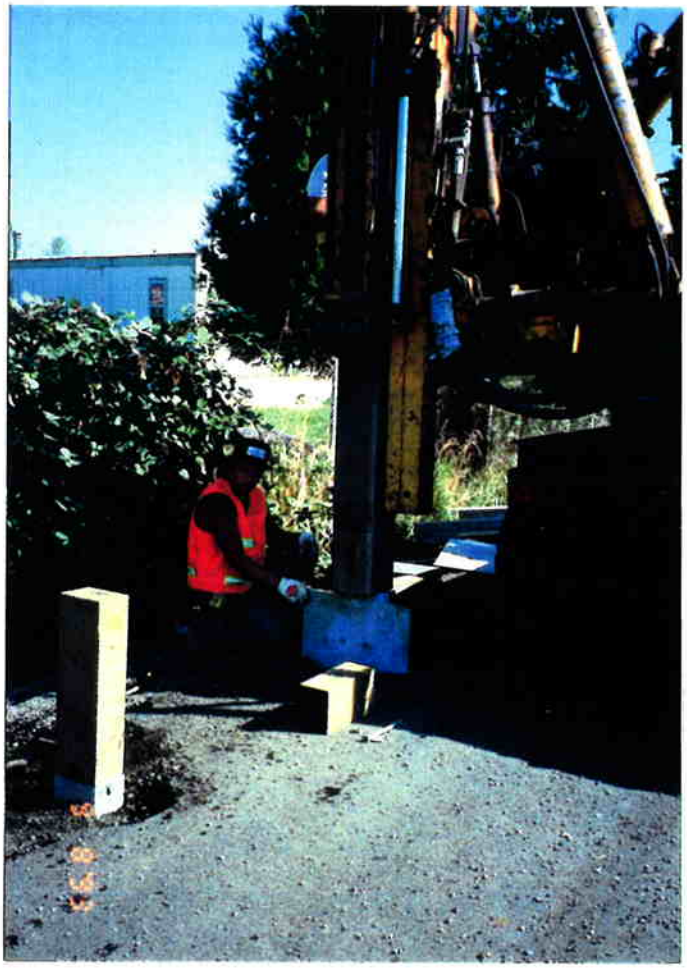

Figure A.1: ET-2000 Soil Plate and Steel Foundation Tube Installation.

Figure A.2: ET-2000 Guardrail Extruder Head, Offset Strut, and Cable Assembly Installation.

Figure A.3: ET-2000 Guardrail Extruder Head, Offset Strut, and Cable Assembly Installation.

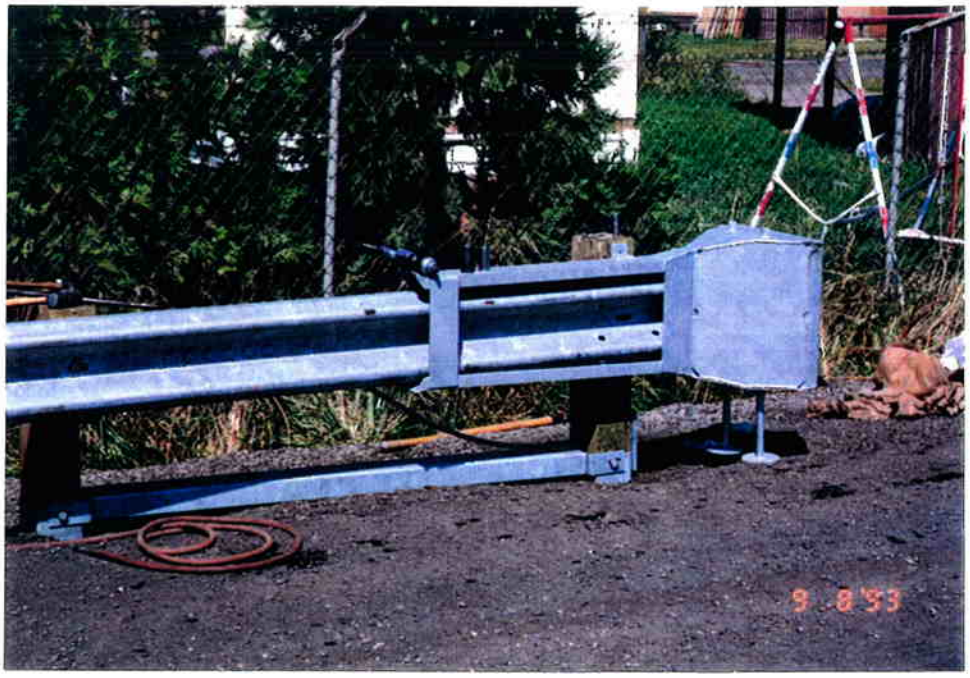

Figure A.4: ET-2000 Guardrail Extruder Head, Offset Strut, and Cable Assembly Installation.

Figure A.5: ET-2000 Extruder Guardrail End-Terminal; unit installation completed.